Enhanced Time-Based Proportional Control

FIELD OF THE INVENTION

This invention relates to time-based proportional control useful for chemical dosage control of water purification systems, such as the addition of chlorine to municipal swimming pools. The invention particularly relates to improvements in a time-based proportional control system for automating dosage control.

BACKGROUND OF THE INVENTION

Virtually all chemical dosage controllers marketed by U.S. Filter/Stranco within the last 10-12 years for use in the aquatic and industrial/municipal markets include a form of proportional chemical dosage control commonly referred to as Time-Based Proportional Control. Time-based proportional control has demonstrated usefulness for applications in cooling towers and other recirculated or batch systems that may experience dramatic loading swings.

Time-Based Proportional control was originally developed for use in spa applications where the chlorine demand will vary considerably due to small water volumes and the ratio of bodies/gallons of water in a spa. Standard on/off control for

1   this application was inadequate, as the only adjustment was

2   the chlorine feed rate. On/off only control suffers from

3   overshooting in either low loading situations, or inability

4   to reach setpoint in high loading situations. A common method

5   of addressing said overshooting is to manually adjust feed

6   rates upwardly during the day and downwardly at night.

7   Time-Based Proportional control is basically a variation

8   of on/off control which utilizes a relay output. Time-based

9   proportional control utilizes a type of pulse width

10   modulation effective to vary the duty cycle of the output

11   relay on-time with respect to the deviation from setpoint.

12   The duty cycle period is typically 30 seconds to one minute.

13   As the sensor moves farther away from setpoint, the

14   percentage of on-time per minute will increase. Conversely,

15   the closer the sensor moves towards setpoint, the less the

16   feeder operates per minute. Whenever the sensor of the

17   controller exceeds setpoint, the feeder is always off.

18   Recent improvements to this control have been the addition of

19   an offset to keep the feeder from completely stopping until

20   the setpoint is exceeded by some value and the ability to

21   change the duty cycle period.

22   A deficiency of the time-based proportional control

23   function is that it fails to operate efficiently because it

1   never reaches setpoint on high loading days-when it is needed

2   the most.

3   Thus, what is lacking in the art is an ability to

4   incorporate a form of deviation compensation which could be

5   described as time-based proportional control with automatic

6   offset, to thus include a functionality, having a relatively

7   small number of resets per minute and a low sensitivity

8   which, when incorporated therein, would eliminate the systems

9   failure to achieve setpoint on high loadings days.

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11 SUMMARY OF THE INVENTION

12   The instant invention is a device and method for its use

13 which includes the addition of a type of deviation

14 compensation function which, in effect, provides an automatic

15 offset ability which is effective for automatically adjusting

16 the offset used in time-based proportional control. In

17 practice actual offset adjustment is not always necessary.

18 An equivalent result is achievable by including a

19 mathematical incrementation of the duty cycle ratio.

20 Inclusion of this improvement finds particular utility in

21 situations like public pools where daily bather load varies

22 depending on weather and other unpredictable factors.

23   Accordingly, it is an objective of the instant invention

1   to teach a method and device to enhance time-based

2   proportional dosing of chemical additives by inclusion of a

3   form of deviation compensation effective to approximate an

4   ideal proportional control response.

5   It is a further objective of the invention to provide an

6   ideal proportional control response by providing time based

7   proportional control with automatic offset.

8   It is yet another objective of the instant invention to

9   provide an ideal proportional control response by

10   mathematically incrementing the duty cycle ratio.

11   It is a still further objective of the instant invention

12   to provide ideal proportional control response by including

13   integration of a measured signal.

14   Other objectives and advantages of this invention will

15   become apparent from the following description taken in

16   conjunction with the accompanying drawings wherein are set

17   forth, by way of illustration and example, certain

18   embodiments of this invention. The drawings constitute a

19   part of this specification and include exemplary embodiments

20   of the present invention and illustrate various objects and

21   features thereof.

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23   BRIEF DESCRIPTION OF THE FIGURES

1   Figure 1 is a graphical representation of prior art on/off

2   control;

3   Figure 2 illustrates a typical on/off response curve;

4   Figure 3 graphically illustrates chemical wastage;

5   Figure 4 illustrates typical time-based proportional control;

6   Figure 5, illustrates the ideal response of a Time Based

7   Proportional control system;

8   Figure 6 illustrates actual proportional control response

9   with loading;

10   Figure 7 shows the programmed response of the Time Based

11   Proportional control with the addition of Integral response;

12   Figure 8 is illustrative of the expected time-based

13   proportional control with integral response in a typical HRR

14   (High Resolution Redox) loading situation;

15   Figure 9 is illustrative of a feed up example utilizing timed

16   base proportional logic;

17   Figure 10 modifies the prior art proportional logic mode of

18   operation by including integration of a measured signal.

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20   <u>DETAILED DESCRIPTION OF THE INVENTION</u>

21   Time-Based Proportional control devices, for example

22   devices available from USFilter/Stranco under the name

23   STRANTROL are an improvement of the On/Off control method.

1   On/Off is commonly used for simple automatic process control.

2   To explain the improvement Time Based Proportional

3   control provides, it is best to first explain the On/ Off

4   control method and its limitations:

5   Note that in Figures 1-8 the X-axis represents time and

6   the Y-axis represents the stated value but is not unit

7   dependent, e.g. for proportional band width (PB), the

8   graphical analysis is independent of whether the setpoint

9   units are in mV, pH, microsiemens, or the like.

10   Now referring to Figure 1, On/Off control, as the name

11   implies, has only two control states, ON and OFF. A

12   disinfection control system feeding a chemical like Sodium

13   Hypochlorite can be used as a good example. When the

14   measured signal (HRR) is below the desired value (setpoint),

15   the controller output is ON and stays on continuously until

16   the measured signal meets or exceeds the setpoint. When the

17   measured signal equals or exceeds the setpoint, the

18   controller output changes to the OFF condition and the

19   chemical feeder stops adding more chemical to the system.

20   With respect to specific chemical feeders, the

21   controlling limitation is the ability of the feed system to

22   tolerate a power on duty cycle of fractions of a minute.

23   High current rotational motor driven pumps can be damaged by

1 short duty cycles such as 30 seconds on, 30 seconds off.

2 Motor-operated ball valves also cannot tolerate short duty

3 power applications. US Filter/Stranco utilizes Time-Based

4 Proportional (TBP) control to regulate their patented CHF-150

5 Calcium Hypochlorite feeder, along with a variety of brands

6 of solenoid-motor diaphragm metering pumps. It is likewise

7 within the purview of the instant invention to utilize time

8 based proportional control to regulate peristaltic pumps from

9 various manufacturers, solenoid valves that control water

10 flow to venturi-type ejectors used to feed gaseous and liquid

11 chemicals into water such as Chlorine, Sulfur Dioxide, Carbon

12 Dioxide, and the like. Additionally, the use of TBP to

13 control special duty solenoid valves that operate under

14 pressure or vacuum to control chemicals (liquid and gaseous)

15 fed, for example, to US Filter/Stranco's patented WATER CHAMP

16 gas induction feeders, CO_2 feeders and the like are also

17 contemplated.

18   As further illustrated in Figure 2, a typical on/off

19 response curve is exemplified. The limitations of this

20 control method are the system lag time and loading. In most

21 industrial applications, ON/OFF control always overshoots the

22 setpoint both on the increase and decrease of the measured

23 signal. In the disinfection control example, when the HRR

1   exceeds the setpoint, the chemical fed to the system stops,

2   but the mixing and distribution of the chemical fed during

3   the lag time continues to increase the system's HRR. This

4   sinusoidal response is very typical for this control method.

5   Restricting the flow rate of chemical to the system can

6   minimize the sine wave amplitude, however during high load

7   events the chemical feed will be unable to meet the demand.

8   The result is that some overshoot is accepted as the

9   limitation of an inexpensive (and simple) control method.

10   As particularly illustrated in Figure 3, the height of

11   the first peak will vary based upon the response time of the

12   system, and the initial deviation from setpoint. The areas

13   under the curve (above the setpoint) also represent wasted

14   chemical.

15   Now referring to Fig. 4, typically Time Based

16   Proportional response improves upon the simple control method

17   by adjusting the feed rate of chemical based upon the

18   measured signal's deviation from setpoint. In Time Based

19   Proportional control, the ON time per minute of the output

20   relay is varied based upon the measured signal's distance

21   from setpoint. This is very similar to the P of P. I. D.

22   control, except the output is not continuous. The advantage

23   can be seen using the same disinfection example. If one

1   turns the Sodium Hypochlorite pump on for 10 seconds and off

2   for 50 seconds when you are only 1 mV below the desired HRR,

3   the rate of HRR rise will be far less per minute and the

4   overshoot will be minimal. Figure 4 illustrates the output

5   feed ratio of time based proportional control throughout the

6   proportional band. The benefit of time based proportional

7   control is a more consistent disinfection rate (less

8   corrosion and fouling), and chemical is conserved because

9   chemical is not being fed to exceed the desired disinfection

10 rate.

11   With reference to Figure 5, the ideal response of a Time

12 Based Proportional control system is illustrated.

13   Proceeding to Figure 6, while Time Base Proportional

14 control is an improvement over ON/OFF control, it still has

15 certain limitations. With large fluctuations of loading,

16 Time-based proportional control may not increase the output

17 enough to compensate. Using the disinfection example again,

18 when an increased loading condition occurs, the controller

19 using Time Based Proportional control will proportion the

20 output to increase the Sodium Hypochlorite feed rate to the

21 system. But as the HRR starts to rise, the controller will

22 reduce the output at the same ratio as the previous loading.

23 The result is a setpoint that may never be achieved, because

1   it now takes more Sodium Hypochlorite to maintain the same

2   HRR (due to loading).

3   In order to address the inability of a time based

4   proportional control system to achieve setpoint during a

5   loaded condition, the instant invention incorporates an

6   additional response into Time-based proportional control that

7   will compare the measured signal to the setpoint with respect

8   to time, and increase or decrease the output time ratio (duty

9   cycle) to compensate for loading as needed. This is

10   accomplished by increasing or decreasing an offset value

11   applied to the control setpoint.

12   Figure 7 depicts the programmed response of the Time

13   Based Proportional control with the addition of selected time

14   duration response. The rate of change would be tied

15   proportionally to the deviation from setpoint and may be

16   adjustable with software. The time base used for the

17   selected time duration response would be different (usually

18   longer) than the proportional time base, is generally set

19   forth as a multiple thereof, and can also be adjustable.

20   Typically, in the recirculated systems currently controlled

21   by time based proportional control, the selected time

22   duration response time base would about 5 minutes.

23   Referring to Figure 8, the figure is illustrative of the

1   expected time-based proportional control with selected time

2   duration response in a typical HRR loading situation as

3   described in the text above. As is readily appreciated, this

4   curve closely mirrors the ideal proportional control response

5   as set forth in Figure 5.

6   Now referring to Figures 9 and 10, the inclusion of

7   integration logic within the standard proportional logic feed

8   up is exemplified. Figure 9 is illustrative of a feed up

9   example utilizing timed base proportional logic, absent

10   selected time duration response logic. Figure 10,

11   specifically the area within the block 1010, modifies the

12   prior art proportional logic mode of operation by utilizing a

13   form of deviation compensation, for example by including

14   selected time duration response logic, which may be

15   manifested as integration of a signal, so as to achieve an

16   automatic offset of the time based proportional control

17   function. The signal must first be verified to be residing

18   within the chosen proportional band width, and it must be

19   further confirmed that the signal is within a particular

20   hysteresis value about the desired setpoint. If the signal

21   is found to be outside of the hysteresis value of setpoint,

22   then a determination must be made as to whether the signal

23   falls within the category of being either steady or

1   retreating from the setpoint during the integral time

2   duration. If the determination is affirmative, then a change

3   in the offset is carried out based upon selecting a value,

4   herein termed the "offset sensitivity value" or OS and

5   multiplying it by the value of deviation from setpoint.

6   Inclusion of this subroutine idealizes the time based

7   proportional response.

8   Ranges of typical values for the calculation of the

9   formulas are as follows:

10   Proportional Band Width (PB) is typically 30 or 60 mV with an

11   allowable range between about 5 and 500 mV. .50 pH units is

12   typical with an adjustable range between about .10 and 5.00

13   pH units. From about 100 to 500 microsiemens is typical with

14   an adjustable range between about 10 and 5000 microsiemens.

15   Time Base(TB): typically 30 or 60 seconds with an adjustable

16   range between about 15 and 600 seconds

17   Signal(SIG): HRR typical range is 0-1000 mV with an instrument

18   maximum range of -1500 to +1500, pH typical control range of 2-

19   12 pH with an instrument maximum range of 0.00-14.00 pH.

20   Conductivity typical range is 1000-5000 microsiemens with an

21   instrument maximum range of 0-10,000 microsiemens.

22   Setpoint(SP): HRR is application dependent but is generally

23   within the range of about 150 to 780. The pH will typically be

1   between 2 and 12 pH with the greatest majority of applications

2   (90%) within the 6.00-9.00 pH range. Conductivity setpoints

3   are generally between 1000 and 4000 microsiemens.

4   Hysteresis values for HRR are 0-10 mV with .02 typically used.

5   Hysteresis for pH is typically .02 or .1 with a range of 0.00-

6   1.1 pH. Conductivity hysteresis is usually 10 but can range

7   from 0 - 1000.

8   Offset Sensitivity Value (OS) is a percentage or fractional

9   percentage with a range between 0 and 100%. The Setpoint

10   Offset Value (SOV) is calculated by taking the Sustained

11   Deviation From Setpoint (SD) as a fractional percentage of the

12   Proportional Band (PB) multiplied by the Offset Sensitivity

13   Value (OS) times the Proportional Band, according to the

14   formula: SOV = (SD/PB)*OS*PB

15   Example: SD= 10 mV;   PB = 30 mV;   % of PB =.33;

16   if Offset Sensitivity Value = 1.00 then setpoint offset would

17   change by .33 * OS * 30 or 10 mV. If OS=.5 then setpoint offset

18   would be 5 mV.

19   It is to be understood that while a certain form of the

20   invention is illustrated, it is not to be limited to the

21   specific form or arrangement of parts herein described and

22   shown. It will be apparent to those skilled in the art that

23   various changes may be made without departing from the scope of

1 the invention and the invention is not to be considered limited

2 to what is shown and described in the specification and

3 drawings.